CHAPTER 3

The Human Nature of Infectious Disease

Abstract Infectious disease raises questions about humans' abilities to eliminate harm through the control of nature. People work to understand microbial life in order to manage the ways microbes mutate, adapt, and evolve, even while recognizing organisms' essential nature. Public health practices from the past and present exemplify this ongoing quest to "solve" disease. Eradicating pathogens persists as a public health objective, even as new microbes emerge in the human environment. "Superbugs" and antibiotic resistance exemplify the problem-solution-problem cycle of disease. Moving from solutions-based thinking enables new imaginings of the microbial world in which humans reside.

Keywords Microbes · Disease · Pandemics · Antibiotic resistance · Public health

In the summer of 2014, people around the world watched news reports of a viral outbreak in West Africa and calculated the risk they had of catching Ebola on the New York subway or in their Berlin apartments. In the fall of 2015, media reports began to circulate about a virus borne by a hardy tropical mosquito, which posed a particular threat to pregnant women. News of the Zika virus led to travel advisories and concerns over attending the Olympics the next summer in Brazil. Since the turn of the century, panic over epidemic disease has surged around outbreaks of "swine flu" and "bird flu," SARS and

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MERS, and diseases like West Nile Virus have crept slowly across the globe and into people's daily lives. Politically-rooted concerns that people will deliberately manipulate microbes to harm populations through bioterrorism or biological warfare amplify fears of contracting a transmissible disease. These moments when microbes surge into the public spotlight, evoke solutionist rhetoric from media, politicians, and the public. In a 2016 speech on Zika, US President Obama said, "You can't solve a fraction of a disease. Our experts know what they're doing. They just need the resources to do it" (White House 2016). Such calls for action are grounded in the belief that scientific expertise, given sufficient time and money, will create a solution.

The modern pandemic reminds citizens both that they live in a globalized, technologized world, and that their bodies are vulnerable to organisms that exist outside human control. In response to their fears, humans both try to mitigate the effects of infection upon individual bodies, and to manage how germs move through the environment. Centuries away from the Black Death of the Middle Ages, people still imagine the sweeping devastation disease might have upon human life, a manifestation of cultural fears of nature still understood through the logics of containment and control. These fears drive people to clinics for vaccines and Tamiflu, and to drugstores for facemasks and hand sanitizer. People also turn to science and its agents who work in laboratories to develop technological interventions like vaccines, or to use computers to model and predict how microbes will bring future harm. Government organizations like the Centers for Disease Control and Prevention have become retailers of disease information, a source of knowledge used by both medical professionals and people surfing the Internet in their own homes.

While humans have always lived with infectious disease, scientific study of microbes—beginning with the germ theory of disease, continuing through the vaccine and antibiotic production, and manifesting today in genomic studies of the human body's relationship with microbes—has shaped how people individually and collectively understand disease threats. Scientists' ability to see, study, and explain how pathogens infect bodies seems to hold the promise that infection can be contained and controlled, "solving" the infectious disease problem worldwide. Vaccines, along with the origination and marketing of products like Clorox and Penicillin, generated the belief that with the right knowledge and subsequent application of modern technologies, humans might be able to manage the organisms in their environment that put them at risk of contracting a disease. Thus, as soon as scientists identified microbes as a cause of disease, people called upon the science industry to solve the problem of infection, including eliminating microorganisms that threaten human life. The scientific production of microbes has enabled solutions-based thinking about human disease.

The promise that infectious disease could be eradicated through vaccines and antibiotics has not manifested and instead exemplifies how the problem-solution-problem cycle generates a series of unanticipated consequences. This case study explores the power of the promise of disease control, revealing ingrained cultural beliefs about the human relationship to biophysical systems, as well as the conviction that science can and should solve the "problems" of the human condition without having to acknowledge the underlying social and political values that also contribute to these systemic issues. Examining the contemporary and historical production of germs shows how microbes have been made as a pernicious, invisible form of nature best known through the lens of science. The techno-scientific fixes of vaccines and antibiotics fall short of achieving eradication, and "solving" one health problem generates new problems that demand new solutions, bringing disease control into the problem-solution-problem cycle. The modern antibiotic-resistant "superbug" is a material effect of this cycle.

As disease-causing microbes elide eradication via scientific fix, it becomes increasingly apparent how entwined pathogenic natures are with human behaviors. This has at least two potential consequences for human populations. First, disease eradication may not prove to be for the benefit of human life and society, nor for ecosystem health and sustainability. Evolutionary science ascribes a vital role to pathogens in promoting strength, mutation, and change. Second, recognizing complexity in people's relationship with disease opens the possibility for societies to step away from a solutionist regime of disease control and prevention in favor of practices that recognize that diseases will forever exist in our world and respond accordingly.

The danger of solutionist language and thinking about disease control is the potential for societies to rationalize increasingly militant disease responses based on a belief that the combined powers of science and social governance can control disease to the benefit of greater good. The desire for permanent solutions may overstep vital conversations about ethics, social values, and human rights. The case concludes by considering how public health actions work to govern the wicked problem of disease, demonstrating how disease must be managed, not solved, and how more nuanced understandings of microbial natures and the human relationship to nature open possibilities for more just and sustainable governance and disease management practices.

Creating the Modern Microbe: A History of Disease Control

In September 2014, an editorial in *Businessweek* proposed that the Ebola crisis could only be contained by deploying military forces. The authors painted a grim picture of Ebola in Africa:

> the situation is desperate. Hospitals have become quarantine zones for the dead and soon-to-be-dead . . . Liberia's government is incapable of managing a response; even elected officials have fled the nation. Doctors and nurses have either perished from Ebola or have left the country due to a lack of support and concern for their safety. Amid the collapse of health-care infrastructure, it is only a matter of time before total chaos descends. The number of infected people is spiraling out of control . . . The Ebola crisis is a natural disaster, like a tsunami or earthquake. But unlike natural disasters with limited global consequences, Ebola is perpetual with far-reaching implications. (Brozak and Noronha 2014)

This depiction of unending, nature-induced disaster shapes how social institutions approach and react to pandemics. The apocalyptic language used to describe the disease paves the way for pleas to solve the crisis and respond to a disaster. In 2014, the United Nations Security Council declared unanimously that Ebola was a threat to international peace and security, and the United States pledged military support to establish a "command and control center" (UN News Centre 2014). Governments instituted quarantine as part of a militant effort to contain the spread of the virus. The outbreak of Ebola evoked a global desire to *contain, command*, and *control* (3 Cs) the virus in order to mitigate a new type of global human disaster.

Achieving these 3 Cs demands broad scientific knowledge and social power. The failure to solve disease problems through scientific fixes leads to managing human behaviors in ways that propose to optimize the effects of the technological interventions. At the core of the political response to infectious disease lies a pervasive belief that the spread of germs can be contained and the risk of infection can be mitigated by intervening in the cycles of microbial life. Disease scientists primarily have worked to develop and prescribe "solutions" to disease outbreaks, including technological medical interventions that seem to overcome human political barriers and predictive modeling of disease behaviors that can be used to plan social interventions. Vaccines, antibiotics, and other drug therapies overlie the sociocultural dimensions of contagion and cultivate the idea that individuals are culpable for disease prevention using techno-scientific fixes. The consequences of the belief that microbial nature can be managed exclusively for human health extend broadly into the human social life, creating a wicked socio-scientific problem.

Today, the fear of germs permeates public debates over vaccination and public schools, global travel and airline safety, immigration and border security, and the regulation of science laboratories. In these debates, as well as in abundant social acts to control infection, people present disease as a problem for science and technology to solve. In part, this is because scientists made the modern microbe. Virus and bacteria are unseen in the environment, but science-derived technologies like the microscope render them visible. Microscopes showed the world to be covered with miniscule organisms, generating in humans a desire to understand how those microbes interact with the world around them and affect their lives in particular.

Microbes complicated our knowledge of the world, but even as scientists work to understand and explain the complexity, society demands that they simultaneously control it. The rise of the science and profession of microbiology bestowed authority upon trained individuals to explain what is seen through the lens, including how these organisms cause disease. Because people can see microbes using simple microscopic technology, they legitimize the need for knowledge and the authority of scientists to generate it. Governments and social institutions vest the scientists who peer at microbes with power to interpret the workings of this invisible world for an audience who have quite narrow concerns about the organisms, centering on their own health, comfort, and survival.

Moreover, the work of scientists binds humans to microbes in a biological system that is simultaneously human and nonhuman, and where ever-blurry line renders the differences indistinct. Microbiologists transformed the scale by which life was known and demanded that the notion of nonhuman nature expand to include microscopic organisms. They also showed that these forms of nature could be located within the human body itself, disrupting boundaries between human and nonhuman, and nature and culture. This dissolution of boundaries challenged a human political system predicated on humans as a distinct species outside of nature. Finally, this knowledge of microbes significantly changed how humans understood their own lives and the interactions that introduce death into human life. As a result, not only was the modern microbe brought into existence by science and technology, but the modern human was remade through this knowledge, particularly in terms of risk and the relationship between humans and the world around them.

In the nineteenth century, the germ theory of disease presented microbes as the cause of human illness, supplanting notions that diseases manifest individual moral failing or were contracted through miasmas or "bad air." This transformative theory located the origins of disease in living creatures that could be brought from the environment into the human body to cause harm. Managing disease was less a moral question and more a concern of how to avoid disease-bearing organisms. The germ theory of disease made it possible to mitigate disease by managing unclean spaces, and empowered people to act upon their environment to manage their individual health. By transforming a moral shortcoming into a failure to act, the germ theory reallocated the responsibility for disease control to individuals and public action.

Germ theory also delocalized disease, expanding the scale of threat to include the world broadly, even as a further scientific study showed that specialized environments enable microbes to flourish. If associating microbes with humans transformed human identities, connecting microbes to environments gave humans a new form of responsibility for managing the world around them. This management applied to individual homes as well as communities, towns, and cities.

From the moment the microscope lens rendered microbes, industries of science and technology set about eliminating the disease by sanitizing the environment. Communities drained swamps as a measure of disease control and as part of broader river management plans. Civic sanitation systems offered another technological fix, separating humans from disease-bearing waste. Tomes (1990) argued that the late-nineteenth-century cult of domesticity created the moral imperative for homemakers to maintain high standards of cleanliness, primarily by consuming goods such as ceramic toilets, water filters, and chemical disinfectants. Such consumer products and public health works seemed to bring disease solutions within the grasp of any individual who could afford to consume or community who had capital to build. Even as harmful associations between disease and the impoverished, immigrant, and "unclean" segments of society strengthened, the promise of disease-free living through consumption and cleanliness swept through society, made possible by pinpointing unseen microbes as the originators of disease.

Locating the source of infectious disease in pathogens outside the human body raised questions of how the body itself might resist infection. The proposal that humans have an "immune system" further defined the body as separate from and in opposition to its environment. Immunologists theorized that taking action upon the body itself could create immunity from disease. In the late eighteenth century, Edward Jenner, a scientist working with poxviruses (like smallpox and chickenpox), observed that people seemed to have varying levels of resistance to disease, possibly due to prior exposure to viruses. He injected healthy humans with fluids from cowpox lesions into dairymaids' hands, and then exposed them to the smallpox virus, a disease that ravaged human society in that era. His test subjects experienced increased immunity to smallpox. This new vaccine technology promised another way to combat disease, by creating human bodies that were inhospitable environments for disease-bearing microbes. Though the earliest vaccinations transferred living matter from one body to another, concoctions created in laboratories facilitated the wide-ranging dispersal of vaccines, spreading hope that disease could be eliminated through a simple prick in the arm. The promise that the application of science and technology could solve the human problem with disease seemed evermore attainable.

Indeed, within two centuries of creating the first vaccine against smallpox, humans had eliminated from nature this disease that killed more than 300 million people in the twentieth century alone (Henderson 2009). The eradication of smallpox, however, also testifies to the role of human cultures in disease management, for though scientists had proven vaccination to be effective in increasing smallpox immunity, containing smallpox required the physical circulation of the technology along with manifold social acts to convince people to be vaccinated. Technology and scientific discovery cannot contain, command, and control, no matter how simple the solution seems. Scientists have developed vaccines for a number of deadly diseases that persist in the population, including measles, polio, whooping cough, and yellow fever.

In part, because disease eradication requires a cultural system that can broadly manage human behavior, disease persists as a wicked problem. Moreover, because microbes are living entities that strive to survive and reproduce, they continually evolve in order to stay alive. New diseases emerge as microbes adapt to survive the assault of the immune system. Like a river continually changing over time which cannot be restored to a singular past moment, the pathogens on the planet that have the potential to harm humans are constantly changing and cannot be targeted at a static moment. Efforts by scientists or technologists to solve the disease problems of the present become outdated as microbes persistently evolve to find new ways to survive on the planet and in the bodies of human hosts.

Furthermore, the social systems that mediate the distribution of vaccine technology disperse its effects unequally through society. The continued experience of polio or measles in poor communities is a problem of social origin, as vaccines have dramatically reduced the occurrence of these diseases worldwide. In the global campaign to eradicate smallpox, health workers realized that distributing vaccines around the globe not only required ratification from numerous nation-states but also social strategies that would convince people to allow foreigners with needles to act upon their healthy bodies. In public controversies over vaccination in the current moment, social systems have again made it easier to blame individuals for disease, now framed as a failure to police oneself against pathogens using the technological fixes provided by modern science.

For example, when a 2014 measles outbreak in California appeared to spread through unvaccinated populations, a UCLA professor argued the event was “100 percent connected” to popular sentiment against childhood immunizations, which had increased the percentage of unvaccinated individuals within the population, saying, “There are some pretty dumb people out there” (Nagourney and Goodnough 2015). The California Center for Infectious Diseases issued statements directly asking unvaccinated individuals to be vaccinated against measles, and county health officials authorized schools to send home students who could not verify vaccination. This governmental response placed responsibility for the health of the population upon each citizen, not only blaming unvaccinated individuals for the outbreak but vilifying their actions and insulting their intelligence. Here, broader questions about global health, economics, and demographics paled beneath debates about individual choices to use vaccinations. Even when officials acknowledge the social and political systems that shape contagion, at the moment disease erupts in a population, the public response tends to focus on individual behaviors like hand washing, public sneezing, and the use of vaccines. Solutions-based thinking connects vaccines to the promise of a disease-free society, without examining the assumptions and politics of the vaccine itself.

Throughout the nineteenth and twentieth centuries, disease science gained credibility because the study of microbial nature led to disease containment, both through sanitation and public health works and the eradication of diseases like smallpox. This science has also brought broader social effects. For example, disease intervention relies upon separation and containment, such as the use of quarantine during the 2014 *Ebola* outbreaks, and the forceful management of environments. These practices materialize a deep-seated belief that the human body separates people from each other and the world around them (Cohen 2009). Not only do we imagine the immune system as a filter to prevent harmful external natures from entering the body, but through disease, we think about interpersonal interactions in terms of risk.

The global response to contain *Ebola* attempted to manage how the virus moved between people by managing people themselves, intervening in centuries-old mourning rituals and scrutinizing traveler's bodies with temperature scanners. Such activities may be rational in the face of death, but must also be understood as the outcome of certain ways of knowing the human-microbe relationship. These actions have consequences in how humans understand their connections to each other and the world around them. To create futures where complex understandings of the human place in the world can operate, we must embrace our bodies as permeable entities that bind us to our biophysical environments and to each other.

Locating the source of disease outside the human body widened a perceived gap between humans and their environment, strengthening the cultural belief that problems can be solved by managing nonhuman environments. As a wicked problem, disease presents complexity because it is so entwined with the corporeal self. Every living body faces "a ceaseless problem of boundary maintenance" (Cohen 2009) as its immune system works to ward off invasions from the world in which it moves. New scientific knowledge, however, overturns the presumption that all microbes constitute a threat and that vaccines can create a perfect barrier against disease.

Research on the complex relations between organisms and their microbes challenges dichotomies of good and bad with new ideas about mutualism, adaptation, and co-survival of species. A century ago, the scientific germ theory of disease created microbes as a primary threat to human health and wellbeing, but scientists have since posited that microbial life contained within the human body is integral to health, and even that individuals are constituted by unique communities of microorganisms, the "microbiome" (Clemente et al. 2012; Shreiner et al. 2015). Consequently, microbes are receiving new scientific and cultural attention as bearers of human life.

Microbes in the Problem-Solution-Problem Cycle

Corporations, government agencies, scientists and medical professionals have presented antibiotics and consumer products that kill germs as science-derived solutions to infectious disease, despite growing evidence that unmoderated use of these agents creates new disease problems. The evolution of antibiotic-resistant "superbugs" is an outcome of the problem-solution-problem cycle of disease control. In the twentieth century, antibiotics provided a miracle-like cure for bacteria-caused infections and were widely used to treat disease. This "solution," however, generated new problems as microbes evolved to avoid harm from anti-microbial treatments. While antibiotics reliably kill bacteria, they also change the worldwide theater of disease, entering a cycle of problems and solutions because the actors on the stage—both human and microbial—are living organisms with the ability to adapt and change. In biophysical systems, the mutable qualities of actors eliminate the possibility for a single, large-scale solution.

Household products and pharmaceuticals with anti-microbial properties provide consumers a seemingly immediate technological fix for the problem of disease. Hand sanitizer, for example, was once used primarily in hospitals but appeared on consumer shelves in the mid-1990s. Effective marketing opened a niche for the glossy gel, and sales grew. In 2002, the CDC reported in the "Guideline for Hand Hygiene in Health-Care Settings" its scientific conclusion that instant alcohol sanitizers were "more effective" for hand antisepsis than antimicrobial soaps, and were better at killing drug-resistant pathogens than soaps and detergents. Such claims in the hands of marketers built public support for using hand sanitizers as a solution to the spread of infectious disease (Owen 2013). Sales climbed steadily for the new product before plateauing in the early twenty-first century. Sales have stayed relatively flat for years, with the notable exception of 2009 during the H1N1 "swine" flu epidemic. Because flu viruses are primarily picked up through the air (spread by coughing and sneezing), scientists questioned the effectiveness of the gel in combating flu, yet sanitizer sales still rose 175 percent during the swine flu outbreak (Fottrell 2013).

In order to be effective, anti-microbial "fixes" to disease problems must be applied in a society on a scale that cannot be matched by the distribution of consumer products. Moreover, product marketing may misrepresent the effectiveness of an antibiotic in preventing individual infection. A product like antibacterial soap may kill germs in a controlled environment, but disease exists in a complex, changing environment with countless unique biological agents. People also have unequal access to consumer products and limited understanding of how these products impact vectors of disease and human health more generally. When the US Food and Drug Administration banned several antibacterial ingredients found in over-the-counter soaps in 2016, they also called for further study of antimicrobial products focusing on how the broad use of these products by consumers, often multiple times a day, diverges from occasional exposure (USFDA 2016). Studies to assess the safety of these products to humans did not anticipate the ways they would be used in practice, and how the microbes targeted by these products would adapt.

While antibiotic technologies offer an effective method for killing pathogens, the spread of these products created new disease problems. Because biophysical systems are dynamic and evolutionary, microbes quickly evolve and adapt to survive. The overuse of antibiotics as an attempt to solve the most inconsequential health problems has fostered the evolution of antibiotic-resistant organisms. Through the process of natural selection, the microbes most resistant to antimicrobial products survive the application of antibiotics and live to replicate their genetic properties in creating the next generation of microbes.

In 2009, the World Health Organization named antibiotic resistance as "one of the three greatest threats to human health," and the CDC estimates it to cause more than 20,000 deaths and 2 million illnesses in the United States annually (WHO 2011; CDC 2013). These adapted microbes have been named "superbugs," evoking the evolution of an organism with exceptional abilities, while retaining the negative association with "bugs" and other undesirable creatures. The term affirms our cultural expectation that bacteria will succumb to antibiotics, identifying microbes that resist antibiotics as "super" or exceptional. We expect antibiotics to destroy microbes, and when they do not, the disease problem shifts: now, it is resistance that must be controlled.

When well-adapted "superbugs" survive a perceived fix, new scientific practices or other cultural interventions must again try to mitigate the spread of the newly mutated germ. Recognizing the rise of antibiotic resistance, health workers are reaching out to prescribers and consumers of antibiotics to limit the overuse of antibiotics. This new awareness of unintended consequences of antibiotic use has the potential to ripple into many areas of social life, not only in health and consumer systems but also through food systems, as the prolific use of antibiotics in agricultural systems is a primary influence in the evolution of "superbugs."

In 2015, the Obama Administration announced the US "National Action Plan for Combating Antibiotic-Resistant Bacteria," promoting nontraditional therapeutics, probiotics, and an international research agenda. The language of the press release and fact sheet accompanying the plan exemplify the enduring myth that solutions exist: "Antibiotic resistance is a global problem that requires global solutions" (White House 2015). The promise cultivated alongside Penicillin that antibiotics, vaccines, and other scientific interventions would create a disease-free world has subsided as scientists and practitioners consider complexities in the lives of microbes that were previously unknown. This political initiative reaches beyond national politics and emergency events to frame a problem global in scope. Even as a US President asserts a continued pursuit of solutions, the scientific community and public at large have gradually opened up to the possibility that a direct war on microbes may not "solve" disease problems, and indeed may cycle back to create a new equation of disease.

One indicator that the problem-solution-problem cycle has generated new ways of thinking about human-microbial life is the "hygiene hypothesis" first put forth in the late 1980s. Scientists propose that exposure to microbes in childhood is essential to the development of the body's ability to fight infection (Strachan 1989, 2000). In a discourse eerily echoing Progressive Era class-oriented associations of disease and cleanliness, the hygiene hypothesis argues that the overuse of antibacterial agents in "developed" nations has led to higher rates of asthma and digestive disorders. The high value on cleanliness, first accessible to those who could afford it, then taken up by the government through sanitation and public health projects, effectively sanitized much of the world inhabited by the wealthy. While achieving the goal of disease suppression for a generation, this work may have unintentionally weakened immunity among the populations living in the disease-free environments they created.

The creation of a "healthy" and immunity-producing microbiome during childhood may require exposure to a diverse and broad spread of "friendly" microbes, particularly bacteria and parasites originating in dirt, water, and vegetation. The widespread use of individual and communal technologies to sanitize and "solve" the problem of disease created new problems for people living in a germ-free (or germ-lessened) world. In the last decade, scientists have explored the role of microbial exposure in immunity, spurring a social movement to increase childhood exposure to germs (Olszak et al. 2012). The first-world return to dirt exemplifies the ongoing effort of individuals to manage their own relationship to disease, intriguingly framed in a new global perspective of dirt.

The concept of a microbiome places a peculiar responsibility upon people (including parents of young children) to manage the concoction of microbes in their bodies which will, through replication of countless generations, be with them through life. In books like *Eat Dirt* and *Healthy Food, Healthy Gut, Happy Child*, medical professionals encourage parents to expose their children to dirt—specifically the microbes associated with dirt—through diet and activities, arguing not only that this practice will protect against asthma and allergies in the long run, but also that it can bring physical and behavioral changes in the short term. Managing exposure to microbes, not eliminating them, becomes the work of daily living.

Where once marketers took up antimicrobial science to sell products that sanitized the world from viruses and bacteria, now the market holds a place for products that help users feel like they are cultivating beneficial microbes within them, a marketable solution to the new problem. Spurred by "probiotic" assertions, products like yogurt grew in sales in the early twenty-first century, despite controversy over the immune-producing claims that eventually led to the ban of the term in European marketing. In 2015, probiotics were a billion-dollar industry in the United States, and the world's largest yogurt company Danone sold $2.7 billion in probiotic yogurts (Mitchell 2016). AOBiome, under the brand Mother Dirt, markets a "biome-friendly" body spray that "replac(es) essential bacteria lost by modern hygiene and lifestyles" (Mother Dirt 2016). It seems the probiotic craze is poised to repeat the pattern of the antibiotic craze a century ago, capitalizing upon a new popular awareness of the microbiome to promote the idea that individuals can control the microbes within their body through consumption and behaviors.

Meanwhile, public and private organizations, from the White House to the Bill & Melinda Gates Foundation, have increased funding for microbiome research through the National Microbiome Initiative, spending hundreds of millions of dollars to "develop approaches to reliably alter microbiomes to benefit individuals, communities, and societies" (White House 2016). This initiative particularly directs the study of the microbiome towards social gain, placing foremost the idea that science must study microbes primarily to understand how they benefit humans, an idea that assumes both human centrality in biophysical systems and the ability of humans to control microorganisms. The 3 Cs appear as reliably in discourses about managing "good" microbes as in battling "bad" ones. Aside from pandemic events like Ebola, the nuanced understandings of the human relationship with disease are growing, but the belief persists that humans can alter nature wholesale to a perceived human benefit without cycling around to further problems and desires for solutions. Defining disease control as a human problem necessitates recruiting citizens to respond. While individuals bear the primary responsibility to govern their biological and social selves to promote healthy human-microbial systems, when scaled up to the level of society, disease control becomes the work of nations and governments.

Scales and Cycles of Disease

Although disease is experienced by individuals, it is also calculated on larger scales. A disease can be calculated at the scale of a population: the number of cases of infection among otherwise healthy bodies. This number fluctuates as new infections take place and other bodies recover from illness, but even as individuals heal, the disease remains present in a population. Still, disease is never omnipresent within a population; it continually ebbs and flows geographically and temporally. Because disease exists on global, national, and communal scales, citizens ascribe responsibility to contain, command, and control to the social institutions they establish to govern collective life. Then, because liberal citizens have the right and responsibility to govern their social interactions as they relate to the risk of contracting a disease, they join in the work of disease control, becoming willing participants in upholding the social good.

In the twenty-first century, the fluidity of microbial disease compounds with the continually evolving nature of microbes and global communications systems to create a world where people can think about their individual risk of infection on a vast scale. Rapid transportation of humans and goods provides vessels that move microbes to new environments as never before. A mosquito carrying the Zika virus might cross the globe in a suitcase in an afternoon, rapidly spreading a disease that might otherwise be tamped down seasonally, even temporarily entering into habitats where the vector insect cannot long survive. The speed with which people and goods can move today creates a sense of risk that often seems immediate even among those who do not move. This global social system exposes disease as much more than contact with a germ; an outbreak is created through human interactions that cannot be eliminated, at the scale of the individual and up to the global.

While microbes have always moved around the world, knowing microbes as agents of a disease has also changed how microbes are positioned on the globe. Desired microbes, such as those used in vaccines or probiotics, are distributed through global laboratory systems or manufactured en masse, while others, such as smallpox, are eradicated. Critics point to the role of laboratory scientists in creating new antibiotic-resistant microbes, sometimes a result of their very work to study antibiotic resistance. People also manipulate the qualities of microbes, both to increase health and knowledge and to cause harm and spread death, primarily for social purposes derived from human values. From the time of those first glances of microbes beneath the microscope eyepiece, people have engineered microbes for particular social objectives, including the use of microbes in weapons of war. In the modern world, healthy bodies are continually at risk, not only from the somewhat-predictable movements of disease through the population (such as the annual flu cycle), but also from the unpredictable behavior of humans attempting to bend germs to their bidding to inflict harm and terror. A microbial disease is a wicked problem because the mutating and evolving nature of microbes presents citizens with an unending number of threats.

Through human-caused and microbe-originating evolution, germs contain the ability to perpetually harm human life. Techno-scientific approaches, even when coupled with social-cultural approaches fail to eradicate disease, and recent studies of the microbiome and bacterial resistance cast doubt upon the desirability of environments cleansed of microbes. Ever-growing knowledge of the ecological function of disease raises the possibilities that microbes, even disease-causing viruses, can be "good," fulfilling a vital ecological role. For example, studies of the role of viruses in gene function show that mutualistic viruses were the key to the domestication of bell peppers and the cold tolerance of rice (Roossinck 2015; Xu et al. 2008). Annihilating these viruses, deliberately or not, might severely impact the ability of these crops to survive. Centuries after their existence was known, the role of viruses and bacteria in broad ecosystem health is only beginning to be studied, and will likely challenge the very notion of disease and its negative associations.

Even the perfect management of microbes, however, would operate through human social systems. In a world where a body is continually at risk of contracting an infectious disease, both sick and healthy bodies must be managed in order to contain infection. The technologies that destroy microbial life create effects within populations because they operate through social acts and political systems. Vaccines and antibiotics entered society via newly created public health systems which gave governments, as a mediator between individuals, nations, and the world, responsibility for creating healthy environments. Bioterrorism and pandemic preparedness activities have further affirmed the government's role in managing human behavior to minimize disease risk. To contain the spread of disease from so many quarters—food, air, travel, and even terrorism—governments require that citizens be aware of their behavior on a daily basis. Thus, the search for solutions to disease problems leads to assigning public institutions with authority over people's health and bodies. Recognizing these outcomes, as discussed in the concluding section of this case, becomes more possible when breaking out of the cyclical search for solutions and scrutinizing the motives that underlie disease governance.

Public Health and the Consequences of Containment

Disease transforms society through the shared experience of risk and the human desire to mitigate harm. Bennett (2010) argues for thinking of publics as "human-nonhuman collectives that are provoked into existence by shared experience of harm." A public cohering around shared vulnerability to disease may then create a government, or assign responsibility to the existing government, to manage that risk. People who govern have a range of disease responses available to them, ranging from allocating research funding to the scientific search for cures, to managing human bodies and biophysical systems to contain and control disease transmission. Most governments respond in manifold ways.

The rise of public health more than a century ago established the prevention of disease as the work of government. Scientists create knowledge about how microbes can be contained, but governments work to ensure that the population participates in prescribed behaviors to fight disease. This governance can be local, national, and/or international in scale, but notably is always intimate, focused on the individual body and on the interpersonal behaviors that make us human and affirm our cultural relations. Sneezing and shaking hands become suspect in a world covered with germs; if we wish to protect ourselves from disease, we must moderate those behaviors.

One form of infectious disease management has been to focus on how a disease is transmitted daily by human behaviors. For example, in the 1980s, a Chinese public health advertisement posed and answered a question: "Where should you spit? In your handkerchief! Tissue paper! The spittoon!" Similarly, a modern Australian ad reminds citizens in rhyme, "The spread of flu is up to you. Flu doesn't spread itself, people spread it." Such campaigns recognize that techno-scientific interventions alone cannot contain a disease, for people must continually regulate their own behavior to protect the population. This language taps into communal values and individual citizenship to motivate people to perform certain behaviors. In turn, citizens bestow a degree of trust upon their governments to identify and promote best practices.

Health promotion campaigns turn disease control into a psychological exercise in redirecting human behavior, relying upon individuals to police themselves against new social mores. These work in tandem with governmental interventions to manage environments, such as water and sanitation systems. Governments also have broad authoritative powers available, such as the enforcement of quarantine or mandatory vaccination programs. Infectious disease challenges us to consider the extent to which we wish for governments to intervene in personal liberties to create a healthy population.

Foucault (2007) theorized a changing relationship between people and disease based upon the new conceptualizations of a population, a collection of beings defined by common biological and pathological characteristics and sharing governance. A population attains security by maintaining a "normal" condition, and the liberal state functions when all citizens work to attain that normalcy. An outbreak of disease threatens the "normal" health of the population, and must, therefore, be mitigated to maintain the security of the population. For this liberal government to function, the state must define normal for its population and then govern deviance. Citizens must assume the responsibility to moderate their own behaviors that relate to the risk of contracting a disease. In turn, the public health system can operate as a tool of the security state, working to *contain*, *command*, and *control* disease within the population to control deviance and secure precious human life. Because there is no solution, subjects and governments continually negotiate the risks and costs of interventions to the individual and population, often in heated debates over ethics, rights, and responsibilities.

In the modern United States, this debate is exemplified in contestations over government-imposed requirements for childhood vaccinations and parents' claims for the right to decide whether their children should be vaccinated. An infectious disease like measles cannot thrive in a population where most bodies have been vaccinated against diseases, allowing a small percentage of citizens to remain healthy even when unvaccinated. However, as the aforementioned 2014 outbreak of measles in California demonstrated, lower rates of vaccination render all unvaccinated bodies vulnerable. When a critical number of citizens refuse vaccination because of a perceived risk to themselves individually, they create a security risk for the population, which must be addressed by government, and then public officials plead for individuals to be vaccinated for the collective good. When public health posters and politicians from the pulpit cry, "It's up to you!" they employ a language that locates the problem and a perceived permanent solution with individuals. The educational message lacks the nuances and complexity that scientists see in human-microbe interactions, establishing instead, the expectation that disease can be contained by socially responsible behavior (and conversely implying that irresponsible behavior is part of a disease problem).

At the core of the debate, then, are human rights to govern our own bodies that must be separated from the scientific knowledge of how to kill microbes. What, for example, should governments require of individuals by rule of law in order to secure a community—or demand of a community in order to secure the nation? These questions can only be addressed through public debate and cultural politics. Scientists cannot determine the ethics of disease control practices, but may provide some insight into how science-based knowledge and subsequent technologies might be applied to control a disease.

During the crisis response of the Ebola virus in 2014, a full quarantine of healthy bodies was called for by nation states, exercising authoritarian rule to maintain the health of the nation. There is a long history of using quarantine to contain the disease, but it is a history tainted by racial injustice and government acts that correlate health, cleanliness, and fitness with skin color and social class (Stern 1999). A court declared a 1900 plague quarantine in San Francisco to be racist in closing nonwhite businesses and in roping off Chinatown but allowing white residents to leave. While quarantine was never enacted, a 1985 poll by the Los Angeles Times found that the majority of the 2,308 survey respondents favored quarantine of AIDS patients. A decision to use quarantine during epidemics masks but cannot separate associations between disease and impurity under a call for health security. When governments impose on human rights in the name of health security they often shirk vital ethical discussions and broader social discourses that would expose injustices and systemic discrimination in these acts. Neutral, nonsocial responses to disease are not possible.

The apparent urgency created by pandemic disease serves a particular social function in affirming the role of the security state to respond to, and even "solve," disease problems. Consider the words of President Obama at the CDC, reported in *USA Today* during the 2014 Ebola events. The newspaper quotes the president saying "the solution is within grasp," even as he described a downward spiral of events in West Africa. Scientific knowledge, coupled with a rapid, militant response, offered the apparent "solution": "The world knows how to fight this disease. It's not a mystery. We know the science. We know how to prevent it from spreading. We know how to care for those who contract it. We know that if we take the proper steps, we can save lives. But we have to act fast. We can't dawdle on this one" (Korte 2014). Scientific and public health knowledge promised to contain Ebola and end the crisis, but that knowledge demanded swift application, in this case, deploying US troops to Africa. The US President promises a solution in words that assure the public that scientists have done their part, now the rest is up to the citizens.

Obama's language calls people to action—caring for victims, taking proper steps, and acting fast without dawdling. By this articulation, the promise of a scientific solution seems to be achievable if the public cooperates. In 2014, as nations debated closing their borders to global travelers, the politics of disease control met the limits of scientific knowledge. Governments shifted blame from science to citizens. Displacing culpability away from scientists and onto human subjects may change the framing of infectious disease as a problem, but does not make it solvable. As a wicked problem, the Ebola crisis could not be solved, though social decisions made on multiple scales of government and in individual lives could manage its immediate social effects. Even eradication of a disease like Ebola does not break free of the problem-solution-problem cycle.

Despite centuries of work in microbiology, people are still learning how complex their relations with microbes are, recognizing that managing disease brings unintended consequences to human and ecosystem health and vitality.

By ceasing the fruitless quest to solve disease problems and opening new discourses that do not rely on solutions-based language, everyday politics of disease can more fully center on the individual and collective rights and values inscribed in public health. Questions concerning how societies will use the knowledge generated through the scientific study of microbes to address disease outbreaks of all sorts must be discussed prior to emergency events, such that the political response can be brought in accordance with social ideals that emerge during public debate, cultural politics, and careful evaluation of our ethical values.

Conclusions

Even as the hopefulness of a swift, global conquest of disease fades in the modern era, the successes of applying science and technology to managing infectious disease are apparent. Ebola, H1N1, and SARS faded from the population. Sanitation increases health and vaccines save lives. Smallpox virus exists only in secured biological laboratories. With lowered disease stressors, however, populations continue to grow and move. As humans gather into tighter urban spaces but also travel increasingly longer distances on a regular basis, they create new paradigms of contagion and risk. Germs are adapting to survive in these new environments, becoming the germs of the future. These microbes have their own evolutionary impetus to grow and change, and their endurance may be inextricable from human survival. Microbes are being remade for another generation.

In society's search for a "solution" to the human struggle with diseases, people have created new microbial realities, and new cultural ideas and political systems are taking shape around the "superbugs" and engineered microbes of the twenty-first century. These politics demand a security apparatus that governs the environments where microbes and humans live together. Because infectious disease management blossomed around the impossible static goal of eliminating disease, it has created microbial environments (which are all environments) as places awaiting a seemingly endless series of technological fixes paired with calls for specific behaviors. By continuing to manage diseases as a problem of nature to be solved, primarily through species eradication, we have waged a scientific and political fight for knowledge of how to destroy germs.

The goal to create a society that does not fear disease is admirable, but work to overcome the fear must accompany any fight to eradicate organisms that may sustain human life in the present and future. Recognizing disease as a social condition and an unending condition of nature, not a problem awaiting a singular solution, opens the possibility of addressing both the cultural conditions and biological processes that create and spread disease. Living with our social "microbiome" means we can recognize germs as an inextricable part of our social institutions, just as we know they permeate biophysical systems.